

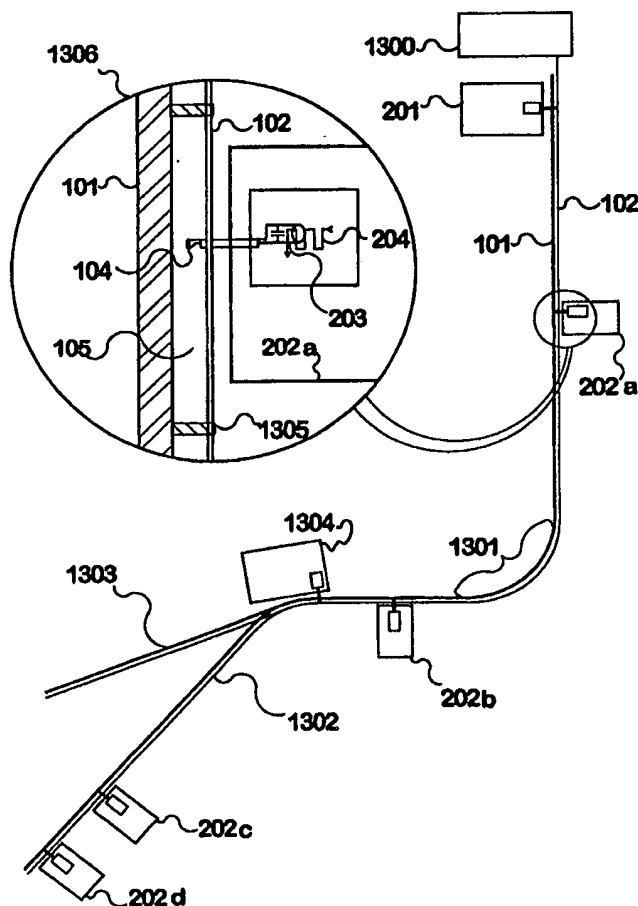


INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶: H02J 17/00, B60M 5/00, 7/00	A1	(11) International Publication Number: WO 98/57413 (43) International Publication Date: 17 December 1998 (17.12.98)
(21) International Application Number: PCT/NZ98/00079 (22) International Filing Date: 2 June 1998 (02.06.98) (30) Priority Data: 328075 12 June 1997 (12.06.97) NZ (71) Applicant (for all designated States except US): AUCKLAND UNISERVICES LIMITED [NZ/NZ]; UniServices House, Level 7, 58 Symonds Street, Auckland 1001 (NZ). (72) Inventor; and (75) Inventor/Applicant (for US only): BOYS, John, Talbot [NZ/NZ]; 15A Island Bay Road, Birkdale, Auckland 1310 (NZ). (74) Agents: PIPER, James, William et al.; James W. Piper & Co., Unicorn House, 300A Richmond Road, Auckland 1002 (NZ).		(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). Published With international search report.

(54) Title: WIRELESS SIGNALS IN INDUCTIVE POWER TRANSFER SYSTEMS**(57) Abstract**

For an inductively powered installation, the invention provides a radio communications channel along a trackway (101, 102) within an extended space (105); physically closely linked to the primary conductors (102) yet electrically quite distinct from the current carried in the conductors typically powered at 10 kHz. The invention facilitates communication between, and control of, vehicles (202x) or fixed devices (201, 1304) along an inductively powered trackway, but does not constrain or adversely affect the provision of power in the track. The space is bounded in part by an electromagnetically somewhat lossy supporting beam (102) (usually made of a metal or of concrete optionally containing metal or ferromagnetic material). The contained RF energy is carried between loop aerials (104) within the extended space for a substantial distance along the trackway, including around bends (1301), with relatively little leakage to the side - hence with little interference to other tracks. Frequencies of from 100 MHz to 1 GHz, at low power levels such as from 1 milliwatt to 10 watts are suitable.



BEST AVAILABLE COPY

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

Wireless Signals in Inductive Power Transfer Systems

TECHNICAL FIELD OF THE INVENTION

This invention relates to apparatus and methods for transferring information or data in a wireless
5 manner from point to point along the route of an inductively powered pathway.

BACKGROUND

Inductive power transfer (IPT) is becoming widely used for passing useful levels of inductive
10 power across a significant gap from a primary inductive conductor to a secondary pickup device;
even a movable consumer of power such as a robotic transporter or a people-carrying bus while
in motion. In applications of this type the advantages of IPT include that there is no physical
current-carrying contact between fixed and moving conductors, so that the power transfer
process does not create sparks, is free of wear, is immune to dust or other contaminants and,
15 there being no bare conductors, the process is relatively safe.

One particular preferred configuration of primary conductive pathway comprises a pair of
power-carrying conductors in a loop configuration, carrying a high-frequency (for example 10
kHz) and preferably low-harmonic or sine wave alternating current at a high current of perhaps
50-500 A. These conductors comprise a primary inductor having distributed inductance and
20 typically are part of a resonant circuit that resonates at the intended frequency. The conductors
are supported on posts from one side (in one example) of a beam that is also used as a rail to
carry the weight of a movable vehicle. The typical length of a single unit of track, as defined by
the length that may be powered by a single source of high-frequency power, is at least 100
metres. In a typical example, there is no requirement for ferromagnetic materials to be laid along

- 2 -

the track. The invention to be described herein is not disabled by ferromagnetic materials, however.

Previous publications by the author (provided by way of further background) include: US 5293308 "Inductive Power Distribution System" to Boys JT & Green AW, and US 5619078
5 "Primary Inductive Pathway" to Boys JT & Nishino S.

Preferably the power conductors are made of litz wire, to minimise the losses caused by "skin effect" at the operating frequency. An intense alternating magnetic field is set up between and around the conductors, to intercept one or more secondary coils, usually aided by ferrite cores to collect and concentrate the flux and lower the number of turns required to reach resonance.

10 Preferably the secondary coil is also made of litz wire. It may carry a high circulating current. One preferred ferrite core shape has in cross-section an "E" shape, with the primary conductors located in or near the two gaps between the three limbs of the "E" and pickup coils located on the limbs and/or the trunk of the "E". In this way, power of the order of a kilowatt or more can be transferred across the space by loosely coupled inductive power transfer.

15 A number of circumstances exist in which transfer of information to or from a vehicle, whether manned or automatic, is desirable or even necessary. For example, a monorail train could provide automatic signalling and verification of response, or telephone services between its driver and the base station, or even complete control and monitoring information if automatically controlled. Automatically guided vehicles in a warehouse could be remotely
20 controlled, and may return video images of storage sites, labels on boxes, etc.

Inductive power transfer configurations were described in the late 19th century. Some were intended to provide motive power to trams or trains, and some were intended to communicate Morse code and railway signal information to trains. Most descriptions appear to be speculative, and the power levels attainable at that time were adequate only for signalling purposes at the
25 level of "Morse code". Means to inductively transfer useful amounts of motive power and at the same time effectively send or exchange useful volumes of data remain undisclosed.

It is considered difficult to include signals having any useful bandwidth (by today's standards) within the currents of large magnitude carried in the primary conductive pathway. This is partly because the pathway is usually resonant. The secondary pickup coils are particularly likely to be

- 3 -

resonant and so are likely to block the propagation of the signals past any one pickup coil. Resonance imposes a "stiffness" minimising the results of attempts to modulate the primary current. The ratio of the signal intensity to the power intensity is likely to be large. On the other hand, the absence of commutation and related occasional arcing in IPT removes one potential source of interference. The high power levels are relatively free of harmonics. Any design for communication means should not compromise the simultaneous transfer of power, or inadvertently reach an unintended destination.

OBJECT

- 10 It is an object of this invention to provide improved means for communication with devices powered by inductive power transfer, or at least to provide the public with a useful choice.

STATEMENT OF INVENTION

- 15 In a first broad aspect the invention comprises an installation comprising at least one power supply device supplying at least one inductively powered trackway having at least one fixed primary conductor capable of carrying an electric current to inductively supply one or more devices capable of collecting inductive electric power; wherein the installation is capable of handling internal communications; the trackway of the installation includes an at least partially
20 electromagnetically lossy surface located substantially close to and substantially along the at least one primary conductor thereby comprising an incomplete partially lossy boundary about an elongated space, the incomplete partially lossy boundary being capable of at least partially confining a radio signal within the space and so forming an effective physical communications channel along the at least one inductively powered trackway.
- 25 Preferably the installation includes one or more devices provided with communications means comprising radio signal transmission means and at least one antenna capable of launching a radio signal into the elongated space.

- 4 -

Preferably the installation includes one or more devices provided with communications means comprising radio signal reception means and at least one antenna capable of intercepting a radio signal from within the elongated space.

Preferably the antenna comprises a loop or hairpin antenna.

- 5 Optionally the antenna comprises a whip antenna.

Preferably the antenna is resilient.

Preferably the antenna is resonant at about the selected carrier frequency.

Preferably the at least partially lossy surface comprises a metallic member.

Preferably the at least partially lossy surface comprises a conductive ground mat.

- 10 Preferably the at least partially conductive surface comprises a partially lossy surface applied over a substantially nonconductive base.

Optionally the least partially lossy surface comprises a ferromagnetic material mixed with a substantially nonconductive base.

Optionally the at least partially lossy surface comprises a concrete beam.

- 15 In a second broad aspect the invention comprises a method for providing communications between two or more devices located at any position along an inductively powered trackway having at least one primary inductive conductor running parallel to an elongated, at least partially electromagnetically lossy surface, wherein the method including the acts of generating a radio signal at a carrier signal frequency capable of substantially being contained within the
20 elongated space, launching the signal into the elongated space between the surface and the conductor using a first antenna at a first position, and collecting a portion of the radio frequency signal using a second antenna at a second position.

Preferably the carrier signal frequency is selected from the frequency range of from 30 MHz to 3 GHz.

- 25 More preferably the carrier signal frequency is selected from the frequency range of from 100 MHz to 1 GHz.

- 5 -

In a further aspect the invention comprises communications means for use with an inductive power transfer system having at least one elongated pathway or track, each track including one or more paired, elongated primary conductors capable of carrying alternating electric power at a high frequency laid end to end and supported a small distance apart from and along an elongated, at least partially conductive support, thereby providing a first elongated space surrounded at least in part with an at least partially conductive border; the communications means comprising the provision of a first antenna placed within the first elongated space and connected to a device capable of transmission of at least one signal; the signal having the form of an electromagnetic field, so that in use the signal is substantially confined to and carried along the first elongated space

Preferably at least one second antenna is also placed within the first elongated space and connected to a device capable of reception of the signal, so that effective communications may be established between any more than one device each having an antenna within the first shared elongated space.

Preferably at least one of the antennae is mounted upon a power consuming device capable of utilising inductively transferred power.

Optionally the power consuming device is capable of motion along the pathway or track.

PREFERRED EMBODIMENT

The embodiments to be described simply represent examples of the invention; and as examples they are in no way limiting as to the range of possibilities that may be apparent to a person skilled in the art. For instance the examples relate to a monorail type of primary trackway. There are many different kinds of communication protocol and many different ways to embody a communication in the form of an electromagnetic field.

DRAWINGS

- 6 -

Fig 1: shows in section the general disposition of preferred antennae and an emitted electromagnetic field in relation to an example support beam and the paired primary conductors of an inductively powered pathway.

Fig 2: shows the surface appearance of an installation as in Fig 1, with a transmitter and a receiver.

Fig 3: shows the sectional configuration of a single-cable primary trackway.

Fig 4: shows the configuration of a primary trackway with two close-together cables.

Fig 5: shows the configuration of a primary trackway wherein the two cables are close to the support beam.

Fig 6: shows the configuration of a primary trackway having three cables; a three-phase system is assumed though one cable could be looped.

Fig 7: shows the configuration of a primary trackway using a concrete support and an earth mat.

Fig 8: shows the configuration of a primary trackway using a nonmetallic support containing embedded granules of ferromagnetic material.

Fig 9: shows the configuration of a primary trackway using a concrete support and an earth mat, where the cables are adjacent to the concrete.

Fig 10: shows the configuration of a primary trackway, with a concrete support comprised of three beams, and an earth mat.

Fig 11: shows the configuration of a primary trackway in which the cables are embedded in a concrete support laid over a dielectric material and over an earth mat.

Fig 12: shows the configuration of a primary trackway using a wooden support which has been coated with a suspension of ferromagnetic granules in a paint.

Fig 13: is a top view of a primary trackway installation, including a bent path.

INTRODUCTION

The problem to be solved is to provide a simple, reliable communication system for inductively powered vehicles, functionally analogous to a method that sends information along wires to each vehicle so that individual communications links can be provided simply and without interference, even in a complex installation such as a rail network or for luggage handling at a large airport. Preferably the communications channel is functionally superimposed on the course of the inductive pathway or track.

This invention is largely based on the surprising discovery that the preferred configuration of a metallic monorail supporting beam together with the primary conductor or conductors that it supports (which together form an elongated space partially bounded by conductive material) forms a channel that can carry an RF signal along the length of the primary conductor, even around bends, with relatively little escape of the signal away from the region of the waveguide. This configuration happens to be a preferred type of primary trackway; others may exist or be devised which also act as wave guides in a manner similar to this example.

The preferred inductive power transfer track has a conductive support beam such as an aluminium or steel box-section or I-beam. The metal beam or rail used in our existing installations is an aluminium extrusion using steel fish-plates to join individual lengths of extrusion. Typically two primary conductors are connected in a loop, which in use carries alternating electric power along the length of the track for use in inductive power transfer.

Concrete support beams appear to be capable of behaving in a similar manner. Perhaps the concrete; which is known to incorporate some water and salts, is sufficiently conductive to guide the signals, or perhaps metal reinforcing within the concrete structure serves that purpose. Or perhaps the concrete has a useful dielectric property at the frequencies tested. The property can be enhanced or made more consistently reliable with the addition of an earth mat (see Fig 7; 702 for example) on the back surface of the concrete.

Although this is only a theory, we believe that propagation may at least in part involve the movement of a launched wave along a somewhat electromagnetically lossy surface – from the point of view of radio waves; the wave tending to bend towards the lossy surface and so act as if it was confined by it. Our trackways (See figs 3 to 12) generally exploit this effect. We do not

- 8 -

usually use a single conductive surface without other material about it in primary trackways for inductive power transfer, although the effect could be demonstrable about a single conductor such as a bundle of fine wires of the type known as litz wire, which can be, on its own, a primary trackway in the form of an open loop. Materials may be deliberately included within or

5 on the surface of a substance during the manufacture of a primary trackway, in order to enhance the effect. An extruded aluminium surface could be scratched. A slightly lossy surface is considered useful for holding a signal in the adjacent area and this could be achieved in the case of concrete or a plastics material by for example including granules of iron, or, more conveniently ironsand (Fe_3O_4 – a form of iron ore) in the concrete before it sets. Ironsand is

10 chemically stable. Wood, or some other existing structure could be painted with a paint including ironsand or another lossy or ferromagnetic material. It may be possible to simply rely on existing properties (in terms of signal guiding properties) of existing structures such as roadways or concrete supports, but the effectiveness of the signal guiding property may then be overly dependent on uncontrolled environmental variables such as humidity.

15 This wave-guiding property (not to be confused with propagation of microwaves within a true waveguide) causes the elongated space formed by the primary conductor(s) and the supporting beam to become a volume within which a radio-frequency field tends to be held. Information carried within the radio-frequency field can be transferred to and from a movable device powered by inductive power transfer and situated somewhere along the primary inductive

20 pathway, using data transfer techniques that are mutually compatible with power transfer techniques. Furthermore, unlike straight-line data transfer such as might be provided using light beams, the presence of bends on a given track is of little consequence to signal levels because the confinement effect also applies around corners. The signal can “jump” from one end of a multi-part trackway to an adjoining one if the two powered sections are placed end-to-end,

25 but not sideways to an unrelated trackway. Unlike broad-area radio coverage (for example by flooding the interior of a warehouse, where multiple guided vehicles may be in simultaneous use) each powered track can be treated as an independent unit. Crosstalk is at a low level, and any one track can in general be operated without regard for other powered tracks in the vicinity.

We have established by trial that signals of the order of 10 MHz or less are not effectively

30 confined by the example inductively powered track, the dimensions of which are about 6 cm

between conductors; 5 cm from either conductor to a planar metal (aluminium) rail side; and litz wire cable diameter about 1 cm. Nevertheless tracks having larger dimensions, or other configurations, may effectively contain signals at lower frequencies – although we expect that the large magnitude of the power available for inductive transfer will make extraction of signals more difficult at lower, more comparable frequencies.

Although our examples and drawings have shown a pair of primary conductors, the effect is still seen with a single conductor, and Figs 3 to 12 depict sections through other variations of primary trackway.

10 **EXAMPLE 1. VHF or UHF radio waves.**

An electromagnetic wave of about 100 MHz or more can be propagated along the extended space between the conductive support beam means and the primary conductive means of a preferred primary trackway. Although this construction is not the same as an ideal waveguide as used in microwave communications or the like, the trackway serves to confine an electromagnetic field within the elongated zone and over a useful distance along the primary conductive pathway.

As long as the signal frequency is reasonably well separated from the system power frequency it is not difficult to transmit and receive signals free of interference from the much larger fields used for power transfer. Please note that the 100 MHz lower frequency “limit” applies to the dimensions used in a prototype track; other configurations or dimensions may allow lower signal frequencies to be used. The “limit” is affected by many opposing or reinforcing parameters and is not a definite value, predetermined by any one physical effect. It would appear that the higher frequency “limit” is at least partially constrained by an increasing tendency of high frequencies to leak out from the space between the litz wires. Lower frequency signals for example of about 15 MHz are relatively similar in frequency to the IPT power, so that the power level as received by an antenna which is due to the primary power or harmonics thereof is relatively large. In contrast, signals of 100 MHz or greater are more easily separated by known filtering methods, and the resulting higher signal to noise ratio provides a greater data bandwidth. It is useful to avoid harmonics of the primary power frequency if

- 10 -

possible. Other than that, the signal guiding properties of the inductively powered track appear to apply over a broad range of frequencies extending up to and perhaps beyond 2.5 to 4 GHz - although we suspect that 1 GHz may be a more realistic upper useful frequency limit.

A signal is introduced, or launched into the extended space by means of an antenna. We have
5 tried a whip antenna in a ground plane configuration but we find that a small coil suitably
oriented gives 20-35 dB more signal transfer. Whip antennae, 4 cm long, were used for trials
with a 304 MHz transmitter. Preferred antennae are of the hairpin style variety - and they may be
resonant at the frequency used to carry the signals. Other varieties of antenna may prove to be
suitable alternatives, or improvements. We prefer to orient the transmitter and receiver antennas
10 horizontally – using the xz plane – as in the configuration shown in Fig 1, with the core of the
coil 104 at right angles to the direction of propagation) so that an H field 105 is generated
vertically and as a consequence an E field is generated perpendicularly to the H field in the
extended space. The fields are somewhat distorted by our very open approximation to a
waveguide.

15 We usually rely on a common-mode signal transmission in which both conductors guide RF at
the same phase and at a similar amplitude – whereas the high current flowing in a pair of
primary conductors can be regarded as a differential source of signal. Therefore a symmetrically
placed antenna, placed so that the magnetic field caused by the currents in the IPT conductors
does not intersect the plane of the loop antenna, results in further rejection of unwanted
20 “signals” produced by the low frequency power.

Launching the field within the elongated space is regarded as a matter of coupling the signal
onto or about the primary conductors, and preferably using both of them. If a hairpin or coil is
to be placed between the primary conductors, it may be oriented with the coil axis facing at the
concrete as shown in Fig 7, or, if it is to be placed within the space between the primary
25 conductors and the support beam, it may be oriented with its axis perpendicular to the primary
conductors as shown in Fig 1. The physical position of antennas on fixed or movable sites is
also dictated by the need to avoid collisions with other structures such as other antennas or the
cores of pickup coil assemblies. Alternatively the antennae or their mounts may be flexible
structures so that if contact occurs it has no lasting effect.

- 11 -

Fig 1 shows an example arrangement. Here, 101 is a beam used to physically support a vehicle (by its wheel(s)); the vehicle being powered by inductively transferred power collected from the primary conductors 102, 103. Supports for these conductors are not shown in Fig 1. Supports are typically made from a tough, resilient plastics material capable of withstanding a voltage of several kV. In use, the power conductors typically carry 50 to 500 A of current at 10 kHz, preferably with a low harmonic content, and in opposing phases generally because they are in a loop configuration. The 10 kHz frequency is here called the system power frequency and is a compromise between a limited semiconductor switching rate and interference caused by harmonics, which together promote selection of lower frequencies, against the smaller resonating components and raised power transfer capability to be expected with a higher selected frequency. The small antenna is 104 - the coil or hairpin loop or similar (depending on the selected frequency).

Fig 2 illustrates a length of track 101 with a fixed transceiver 201 capable of communicating with a moveable transceiver 202. We have found a useful field extending outwards to about a quarter wavelength or about 250 mm at 304 Mhz in the direction indicated by the symbol "A". By symmetry, a similar injecting coil (hairpin) mounted on a movable vehicle in or about the same space as the coil 104 is capable of collecting at least some of the energy within the extended space or alternatively injecting energy into the extended space to be picked up by the coil 104. There is ample tolerance within the extended space to provide clearance between fixed antennae and any moving antennae passing by, although the possibility of collision should be provided for.

In antenna comparison and range tests experiments at an example frequency of 304 MHz, power -10 dBm and a straight track, we observed received powers as in the following table:

<i>Loop antenna</i>	<i>Whip antenna</i>
-22.5 dBm at 1 m distance,	-44 dBm at 1.5 m distance
-23 dBm at 2 m,	-42.5 dBm at 2 m,
-22 dBm at 3 m,	-46 dBm at 3 m,
-23 dBm at 4 m,	-47.5 dBm at 4 m,
-20.6 dBm at 5 m,	-47 dBm at 5 m
-22 dBm at 6 m,	
-20 dBm at 7 m,	
-22 dBm at 8 m,	
-23 dBm at 9m	

We found that loop antennae offered a better performance. Of course there may be antenna configurations other than whips which perform adequately at the frequency in use (far below the resonant frequency of the whip used) but the use of a hairpin or loop appears to be one suitable solution, preferably tuned to resonance at a convenient carrier frequency. We found that after traversing a corner of radius 15 m, the signal at a sampling point 12 m from the signal source was for the loop antenna -22 dBm and at about the limit of detectability of -73 dBm for the whip antenna. This is not to say that the invention cannot be used with whip antennae in combination with tracks having bends; this measurement simply reports an early experimental result.

We have found a useful field extending outwards from the track (perpendicular to the track) to about half a wavelength, while the field strength is about 20 dB down at 1 metre and 60 dB down at 3 metres; a likely inter-track spacing. Therefore it appears that crosstalk is unlikely to occur between parallel tracks.

Given that we have found that carrier frequencies of the order of 100-300 MHz, 900 MHz or even 2.5 GHz are effective in this example, it is evident that broad-band, two-way communications can be established between a fixed transceiver and one or more movable

transceivers along a track; limited primarily by the capability of the transceivers selected. Example transceivers include wireless WAN devices which are commodity items at this time. These would allow computer-to-computer communications just as if the transceivers were actually connected by means of copper wire or fibre-optic cable on a network.

- 5 Interference between the high level of "signal" used for power which is inevitably present, and the relatively small level used for communication is small. Suppose that a 60A current at 10 kHz is present; then assuming a 20 dB per decade falloff in field strength (reflecting harmonic content, and transceiver rejection) this effectively becomes a 6 mA current at 100 MHz and so a transceiver having a 1 mW output should be able to produce an over-riding signal. Substantially
- 10 symmetrical placement of the injection coils in relation to the position of the inductive power field assists in rejection of the power. Radio frequency power levels such as from 0.1 to 10 watts would typically be used, depending on a number of factors such as preferred antenna types and configurations, desired bandwidth, operating frequency, and range.

15 **EXAMPLE 2. 304 MHz radio waves.**

- We successfully tested a domestic garage door-opener device, running at about 304 MHz. In addition, a transmitter and receiver capable of sending data at 304 MHz has been built. It employs an encoder chip and matching decoder chip to use a serial data link, a surface-acoustic-wave filter to generate the 304 MHz signal in the milliwatt level, and uses a two-turn coupling
- 20 coil 203 above (or on the other side of a printed-circuit board from) an inductor 204 laid down on the printed-circuit board to collect radio-frequency power for transmission. The receiver uses a super-regenerative detector in a circuit configuration well known in the art. This combination is cheap. To provide a link in reverse, a different frequency band could be used, or a protocol such as HPIB, IPT2PTC, or the like. A suitable protocol would assist in avoiding conflict
- 25 between more than one transmitter attempting to transmit at the same time.

In our experiments we tested a Motorola type MC145026 encoder chip which is capable of transmitting data and corresponding addresses along a data pathway to a type MC145027 decoder chip; in this instance attached to the receiver. Only those messages correctly addressed to the addressable decoder chip were passed out from the decoder chip. This family of chips is

capable of a mode of synchronised operation in which the receipt of each pulse can be acknowledged by a transmission in reverse to the original transmitter. This family offers 4-bit binary data (for control purposes, for example) and 5-bit ternary address capability. Of course other circuits can be devised; some capable of communicating over greater bandwidths such as those required for image transfer. We shall not describe in detail the many kinds of data that may be sent along the "waveguide" track, for there are many, generally application-dependent possibilities.

Figs 3 to 10 illustrate sectional examples of other track configurations in which a similar radio signal guiding capability is expected; again using the elongated space formed between the primary conductors and an at least partially conducting support structure, but with conductor placement variations and other types of support beam. In Fig 3 the single litz wire conductor 302 may be used as an outgoing part of a loop, and the support beam 101 may serve as the return part of the loop. In Fig 4, a pair of conductors 401 are run close to each other in order to minimise the radiated magnetic field and allow a greater reach of primary conductors. In Fig 5 the pair of conductors 501 are closer to the support beam 101. In Fig 6, a three-conductor configuration 601 is shown; perhaps three-phase resonating current, but more likely one conductor has been doubled back on itself in order to double the magnetic field available in that region. Fig 7 shows a concrete support 701 and an earth mat 702. Fig 8 includes lossy (filled) concrete 802 and in this example the conductors 801 are close to the concrete. Fig 9 shows a more complex arrangement of concrete; strips 901, 902 and 903 in section, and an earth mat 702. Fig 10 illustrates a common situation in which the conductors 1000 are actually buried in a support matrix 1001, and a conductive earth mat 702 assists in guiding the radio signals.

Concrete generally includes some moisture and usually some metallic reinforcing structure, which may further supplement the field guiding effect. Nevertheless we prefer to provide a definite earth mat or ground plane 702, as shown in those illustrations including a concrete support. This earth mat assists in launching the signal. A conventional railway line having iron rails is not expected to be as effective a wave "guide" as one having aluminium rails, because of losses within the iron.

Materials may be deliberately included within a substance during the manufacture of a primary trackway, in order to enhance the effect. A slightly lossy surface is considered useful for holding

- 15 -

a signal in the adjacent area and this could be achieved in the case of concrete or a plastics material by for example including granules of iron, or, more conveniently ironsand in the concrete before it sets. Ironsand is chemically stable. Wood, or some other existing structure could be painted with a paint including ironsand or the like. It may be possible to simply rely on existing properties (in terms of signal guiding properties) of existing structures such as roadways or concrete supports, but the effectiveness of the signal guiding property may be overly dependent on day-to-day environmental variables such as humidity.

EXAMPLE 3. An installation.

Fig 13 is a diagram showing an example of an entire installation employing communications in the form of RF messages passing along the trackway. The track is provided with power at typically 15 kHz by power supply 1300. This power passes along conductors 102 (superimposed here); the conductors run alongside a support beam 101. A controller device 201 communicates at a radio frequency such as a carrier of 304 Mhz along the space 105 with a number of devices; 202a, 202b, 202c and 202d being mobile consumers capable of moving to any position along the track. 1304 is a points actuator taking power from the resonant conductors 102 and control information from a transceiver by way of the channelled radio signals just as the mobile devices do. The trackway includes several bends such as 1301, and it should be noted that the signal remains effectively confined within the space 105 even around bends. This track includes two branches 1302 and 1303 and normally the signal would be split evenly between branches. We assume that all communications are between the base station 201 and any other device. It is likely that communications from one branch to another would require that the signal be relayed through a common device such as 201. The magnified view 1306 is of the relationship between device 202a and the trackway; it shows a support beam 102, a pair of superimposed conductors 102 supported on insulators 1305, a space 105, and a loop antenna 104 held approximately within the space 105. The loop antenna is connected to a transceiver within the device 202a by coupling inductors 203 and 204.

VARIATIONS

One aspect of a conveying belt or other pathway is vehicle speed. In the absence of specific control by means of an information-carrying data pathway, all vehicles on an inductively
5 powered track can be controlled simply by switching the track power on or off. This has been termed the "Donkey" control system by us. Given the possibility of selective addressing of individual vehicles (perhaps also with a proximity detector on each end of each vehicle to sense other vehicles), we could provide a "Smart Donkey" system capable of increased throughput.

An automatically guided warehouse truck may be equipped with a solid-state camera for
10 guidance purposes or for reading codes on labels affixed to goods on racks as it passes by; image transfer to a base image analyser generally uses a relatively high data transfer rate which can be supported by the invention. In a warehouse, some vehicles may be "supervisors" to view stocks by means of cameras, while others may be "loader/carriers" that pick up and transport goods. With any degree of complexity, the capability of any movable vehicle to report position
15 (such as the last marker passed by) to a supervising control station is of use. A warehouse may have at least one remotely guided vehicle fitted with a video camera aimed at labels placed on stored containers; and a control station equipped with image processing software to determine the nature of goods in view at any time, that can in real time instruct a vehicle to transport goods about the warehouse. Another application is in directing one or more vehicles to stop or move,
20 to carry out other acts such as "grab or place", and a further possibility for communications is in supervising the control loop that maintains the secondary current in the pickup coils at a desired level. For people movement, the vehicle can for example see whether or not people are waiting at a boarding site, and detect obstructions along a line.

Possibly the waveguide would be used for wireless computer networking, for which purpose a
25 range of commercial products are available and presumably the only adaptation required may be in terms of the antenna and transceiver.

If the IPT system was to be used for people-moving applications, the communications channel could be used for vehicle control, track information, communicating with on-board staff, providing personal messages, the use of cellular telephones, or the like.

- 17 -

Although we have assumed that the invention is likely to be used for controlling moveable or moving devices consuming power from the inductively powered track, it may be instead used to (for example) help multiple power sources to co-operate in supplying power to the track, such as by synchronising the phase of the power supplied between widely separated sources which might otherwise develop local, mutually incompatible resonances, or in varying the level, according to actual or anticipated demand. For example a vehicle about to accelerate may request a raised power level from one or more power supplies.

The invention may be used to control fixed devices such as points (switches) on the rails.

The invention may be used with primary inductive pathways having configurations other than the supporting monorail beam shown in Fig 1. See Figs 3 to 10. In the case of a roadway installation, a conductive strip or earth mat 702 may be placed below a pair of side-by-side conductors so that a similar extended space is formed. The space may be kept open (such as by using a plastic pipe to define an air-filled space), or the space may be filled with a dielectric such as road metal.

The primary conductors themselves may be configured as strips (and laid with the wide surfaces facing each other) rather than as substantially circular cables, whereupon the space between the strips may serve as a waveguide as described above.

The invention could be used with commutative (brushed) power transfer equally well, except that electrical noise caused by arcing or the like may be expected to detract from the signal to noise ratio applying to inductive power transfer, where arcing is of course absent.

ADVANTAGES

The invention provides a number of advantages, for example:

1. By providing a physical channel for communications, inherently aligned with the course of the inductive power regardless of direction or curvatures, the invention permits reliable bidirectional communications between one or more devices such as moveable vehicles along an inductively powered track, and one or more stationary sites. The invention inherently links items having "a common interest" together.

2. The transfer of information may continue while the power system is in an abnormal state or simply off; useful in fault conditions. For example, passengers stuck in a tunnel by a power cut.

3. The invention can be put into practice with relatively little expense.

5 4. By permitting a broad-band, high-capacity yet physically confined channel for communications, the invention allows for the co-existence of multiple communication links capable of carrying even detailed image information. (Here, "multiple" can refer to either or both a number of co-existing links, one on each of parallel primary pathways, or links co-existing on the same pathway but kept separate by some form of addressing or multiplexing
10 protocol).

5. Crosstalk between a parallel pair of inductively powered tracks is small because of the waveguide-like confinement of a given signal within one track. Thus adjacent tracks can be operated on the same or a similar carrier frequency without confusion of signals; an advantage in a complex layout of tracks and where a given vehicle may change from one set
15 of tracks to another.

6. By providing a channel physically closely linked to yet electrically quite distinct from the current carried in the primary conductive pathway, the invention facilitates communication with and control of vehicles on an inductively powered track.

20

Finally, it will be appreciated that various alterations and modifications may be made to the foregoing without departing from the scope of this invention as set forth.

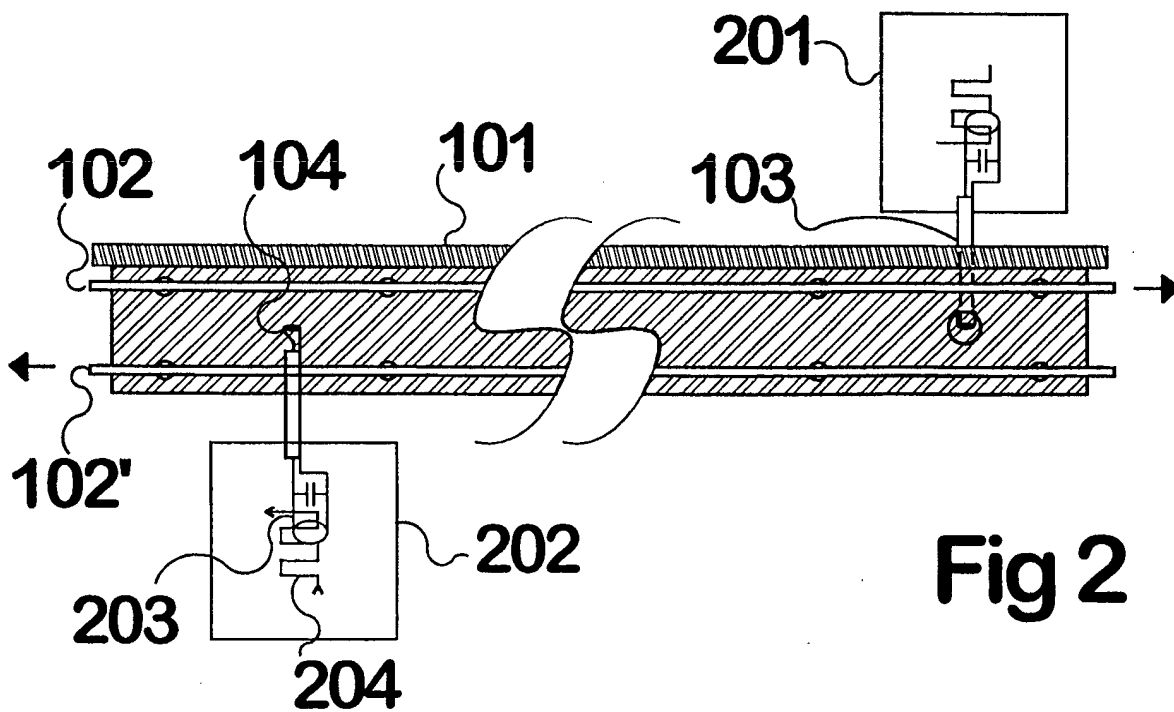
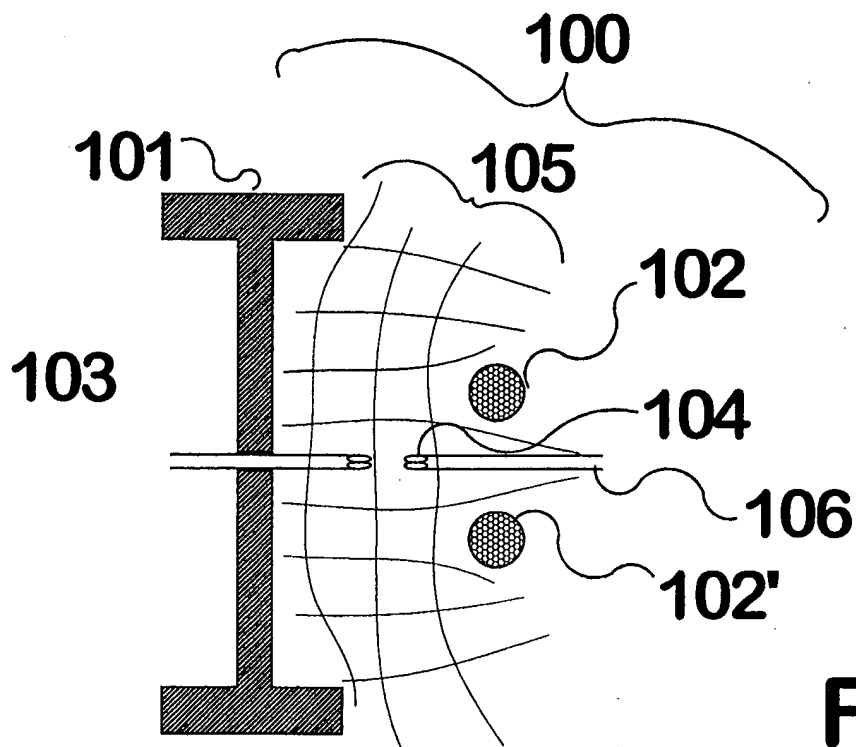
CLAIMS

1. An installation comprising at least one power supply device supplying at least one inductively powered trackway having at least one fixed primary conductor capable of carrying an electric current to inductively supply one or more devices capable of collecting
5 inductive electric power; *characterised in that* the installation is capable of handling internal communications; the trackway of the installation includes an at least partially electromagnetically lossy surface located substantially close to and substantially along the at least one primary conductor thereby comprising an incomplete partially lossy boundary about an elongated space, the incomplete partially lossy boundary being capable of at least
10 partially confining a radio signal within the space and so forming an effective physical communications channel along the at least one inductively powered trackway.
2. An installation as claimed in claim 1, *characterised in that* the installation includes one or more devices provided with communications means comprising radio signal transmission means and at least one antenna capable of launching a radio signal into the elongated space.
- 15 3. An installation as claimed in claim 1, *characterised in that* the installation includes one or more devices provided with communications means comprising radio signal reception means and at least one antenna capable of intercepting a radio signal from within the elongated space.
4. A trackway for an installation as claimed in claim 1, *characterised in that* the at least
20 partially lossy surface comprises a metallic member.
5. A trackway for an installation as claimed in claim 1, *characterised in that* the at least partially lossy surface comprises a conductive ground mat.
6. A trackway as claimed in claim 1, *characterised in that* the at least partially conductive surface comprises a partially lossy surface applied over a substantially nonconductive base.
- 25 7. A trackway as claimed in claim 1, *characterised in that* an at least partially lossy surface comprises a ferromagnetic material mixed with a substantially nonconductive base.
8. A trackway as claimed in claim 1, *characterised in that* the at least partially lossy surface comprises a concrete beam.

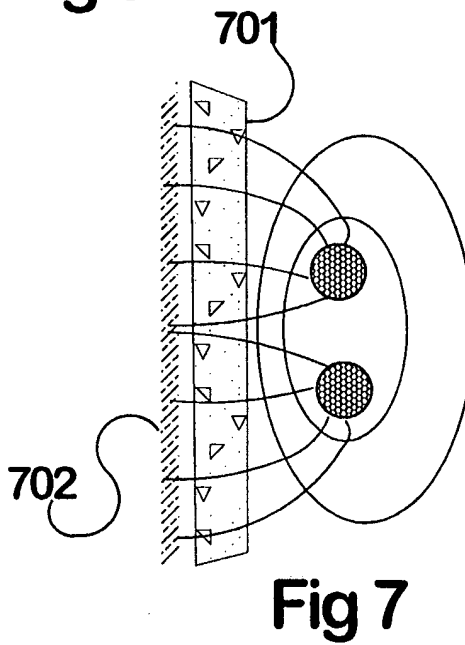
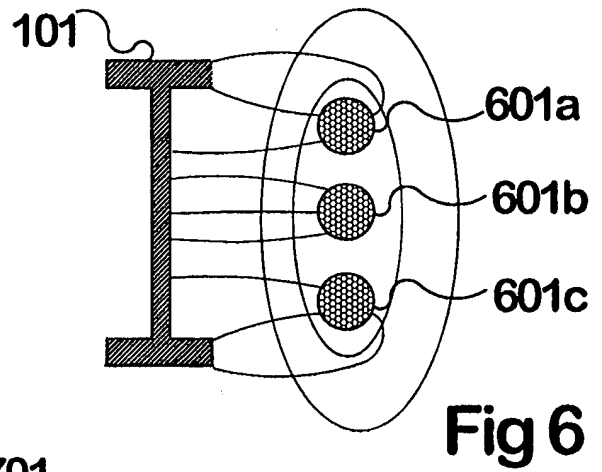
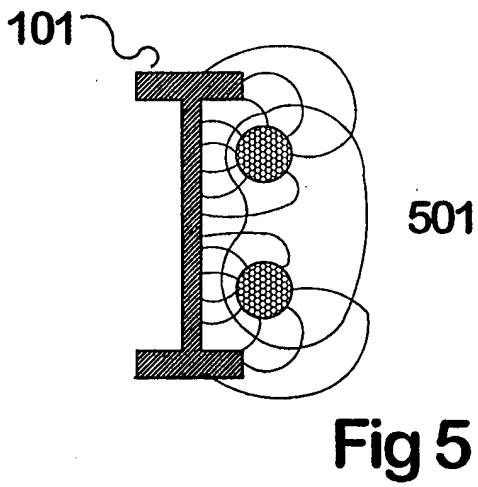
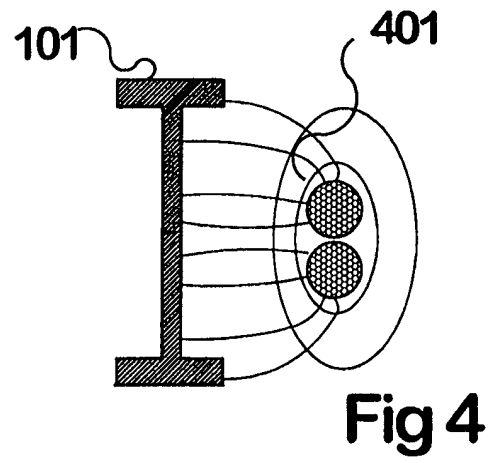
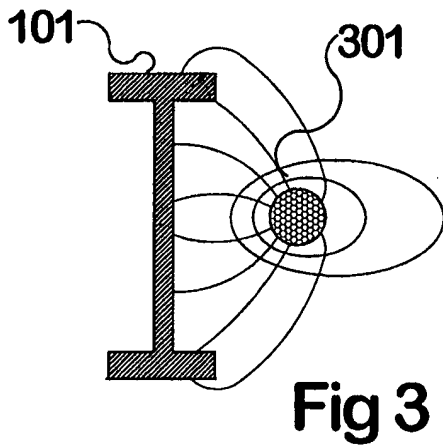
- 20 -

9. A method for providing communications between two or more devices located at any position along an inductively powered trackway having at least one primary inductive conductor running parallel to an elongated, at least partially electromagnetically lossy surface, *characterised in that* the method including the acts of generating a radio signal at a carrier signal frequency capable of substantially being contained within the elongated space, launching the signal into the elongated space between the surface and the conductor using a first antenna at a first position, and collecting a portion of the radio frequency signal using a second antenna at a second position.
10. A method as claimed in claim 10, *characterised in that* the carrier signal frequency is selected from the frequency range of from 100 MHz to 1 GHz.

1/4



2/4



3/4

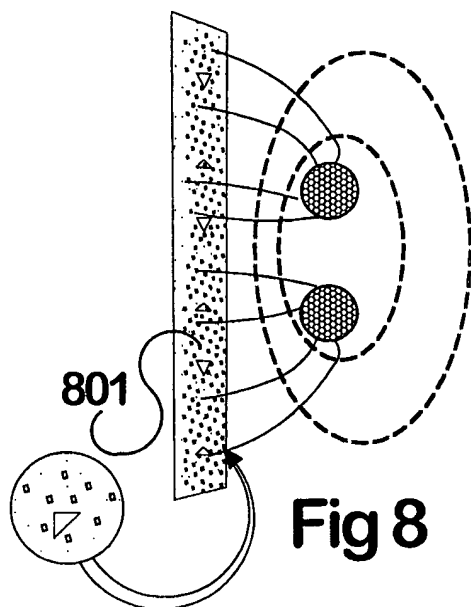


Fig 8

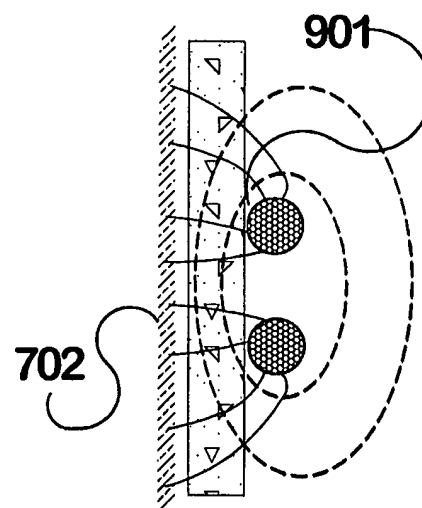


Fig 9

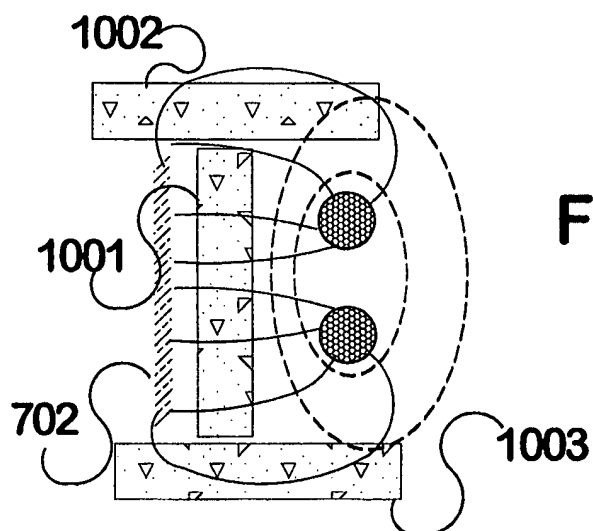


Fig 10

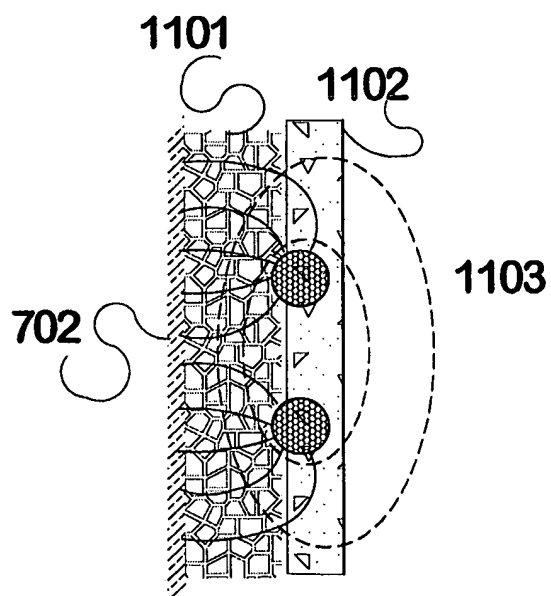


Fig 11

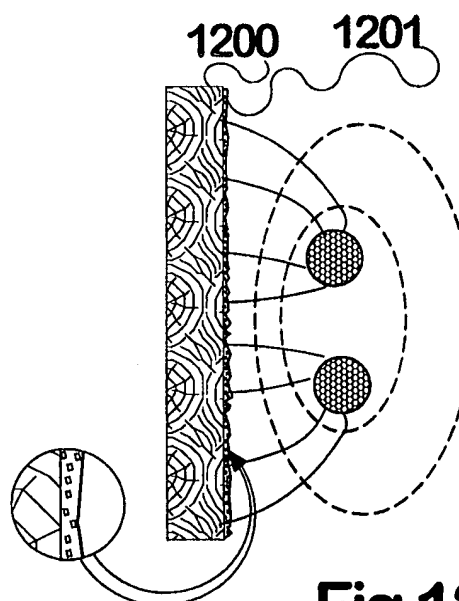


Fig 12

4/4

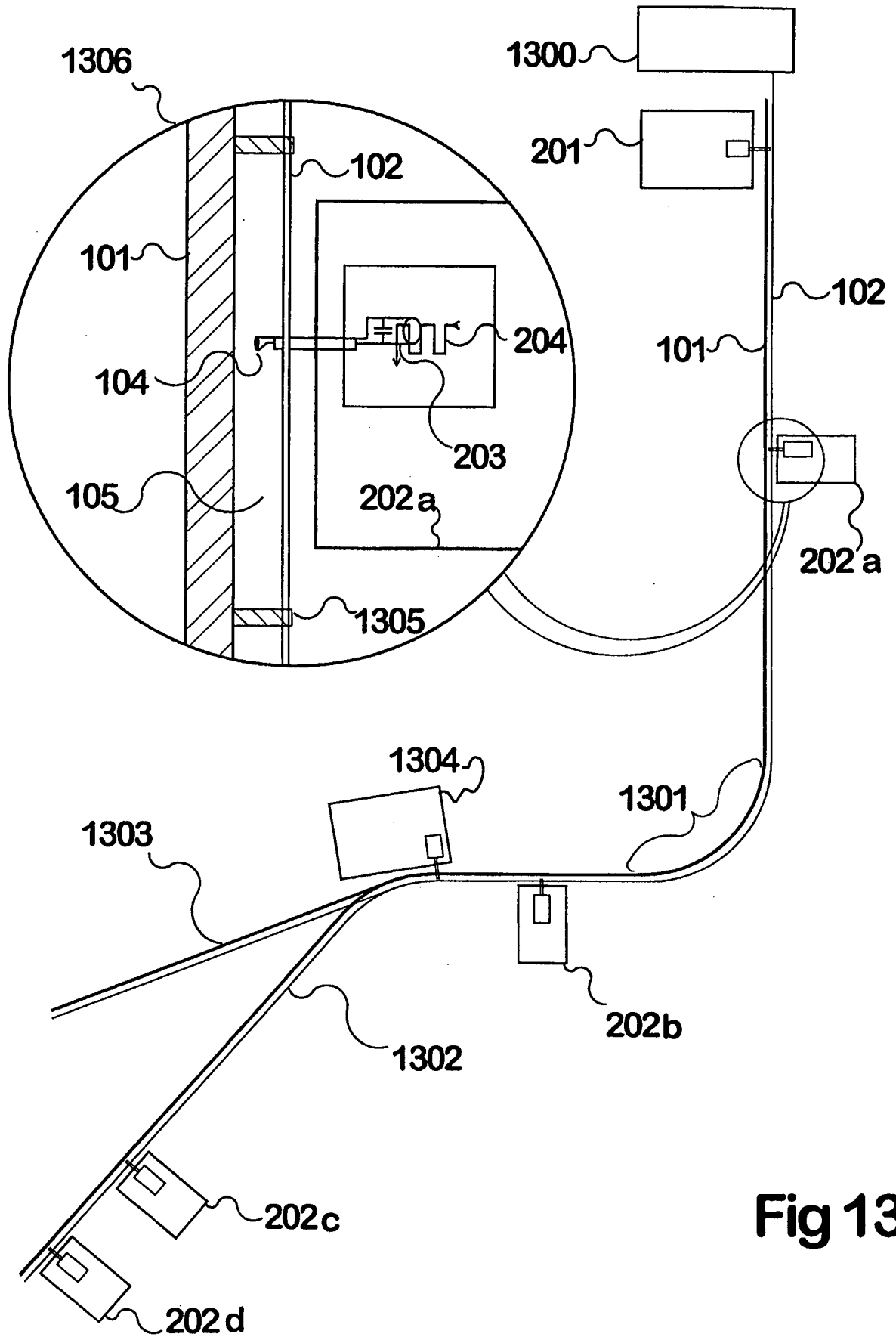


Fig 13

INTERNATIONAL SEARCH REPORT

International application No.

PCT/NZ 98/00079

A. CLASSIFICATION OF SUBJECT MATTER	
Int Cl ⁶ : H02J 17/00, B60M 5/00, B60M 7/00	
According to International Patent Classification (IPC) or to both national classification and IPC	
B. FIELDS SEARCHED	
Minimum documentation searched (classification system followed by classification symbols) IPC H02J 17/00, B60L 9/1C, B60M 5/00, 7/00, B61L 3/1C	
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched AU: IPC as above	
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) WPAT: [[[COMMUNICAT: OR POWER OR SIGNAL:] AND (GUIDE# OR CHANNEL# OR WAVEGUIDE#)] OR [(INDUCTIVE) POWER() TRANSFER)] OR [INDUCT: AND (COMMUNICAT: AND POWER)]] JAPIO: AS ABOVE.	
C. DOCUMENTS CONSIDERED TO BE RELEVANT	
Category*	Citation of document, with indication, where appropriate, of the relevant passages
A	US 4354649 A (MURR et al.) 19 October 1982 Column 1 line 31 - column 3 line 48
A	US 4550444 A (UEBEL) 29 October 1985 Abstract; column 1 line 65-column 2 line 59
A	Patent Abstracts of Japan, E-1454, page 1, JP 5-176483 A (SHINKO ELECTRIC CO. LTD.) 13 July 1993 Abstract
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C	<input checked="" type="checkbox"/> See patent family annex
<p>* Special categories of cited documents:</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier application or patent but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"&" document member of the same patent family</p>	
Date of the actual completion of the international search 8 September 1998	Date of mailing of the international search report 17 SEP 1998
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No.: (02) 6285 3929	Authorized officer JUZER KHANBHAI Telephone No.: (02) 6283 2176

INTERNATIONAL SEARCH REPORT

International application No.

PCT/NZ 98/00079

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5293308 A (BOYS et al.) 8 March 1994 Abstract	1-10
A	US 5619078 A (BOYS et al.) 8 April 1997 Abstract	1-10
P, A	US 5706735 A (LUND) 13 January 1998 Abstract; column 28 line 51-column 31 line 62	1-10

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/NZ 98/00079

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report				Patent Family Member			
US	4354649	CA	1136251	ES	487821		
US	4550444	CA	1186741	CH	656100	DE	3040137
		YU	2502/81	ZA	8107014		
US	5293308	AU	12373/92	CA	2106784	EP	577611
		EP	818868	MX	9201100	NZ	237572
		WO	9217929				
US	5619078	AU	40934/93	AU	40935/93	EP	640254
		EP	640255	WO	9323908	WO	9323909
US	5706735	AU	61587/96	EP	839102	US	5598783
		WO	9640545	US	5590603	US	5590604

END OF ANNEX

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☒ ~~FADED~~ TEXT OR DRAWING
- ☐ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☒ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☐ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.